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A new plane type sensor for concentration measurement in liquid

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Abstract

In this paper, we propose a new plane type sensor for measurement of the liquid. In the proposed sensor, the PVDF films with the transparent conductive electrodes are respectively arranged on the surface of a LED and a photodiode. The optical properties of the liquid are measured using the LED and the photodiode, and the electrical and ultrasonic properties are measured using the PVDF films on the surface of the LED and photodiode. Therefore, the optical, electrical and ultrasonic properties at same space are measured by the proposed sensor. Three parameters in the sample liquid were estimated by the proposed sensor.

Keywords : Linear array; Optical property; Electrical property; Ultrasonic property; Ingredient concentration;

1. Introduction

The ingredient measurement technique in a liquid such as dairy beverage or coffee, including fat content, is one of the most interesting research topics in the food industry, especially, for beverages and has been researched by using a variety of optical, electrical, and ultrasonic sensing methods. The aim of our study is to develop a new system for measuring several ingredients in liquid. We propose a new plane type sensor. In the proposed sensor, PVDF films with indium tin oxide (ITO) electrodes as the transparent conductive electrodes are coated on each surface of a light emitting diode (LED) and a photodiode. The optical properties of the liquid are measured using the LED and the photodiode, and the electrical and ultrasonic properties are measured using PVDF films on the surface of the LED and photodiode. Therefore, the optical, electrical and ultrasonic properties are measured by the proposed single sensor, and several parameters of the liquid are detected from their measured values. In this paper, three parameters, - red color, glycerol and sodium chloride (NaCl) concentrations -, were estimated by the proposed sensor.

2. Method

Fig. 1 shows the schematic diagram of the proposed plane type sensor. The optical properties of the liquid are measured by light emitting diode (LED) and the photodiode as shown in Fig. 1(a). In Fig. 1(b), the electrical properties are measured by using the transparent conductive electrodes (ITO electrodes) on the surface of each

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PVDF film which is pasted on each surface of the LED and photodiode.In addition, the ultrasonic properties are measured by the PVDF films as shown in Fig. 1(c). Therefore, the optical, electrical and ultrasonic properties in same space of the liquid are measured by the proposed sensor, and it is possible to detect several parameters in the liquid such as concentrations of the ingredients and temperature.

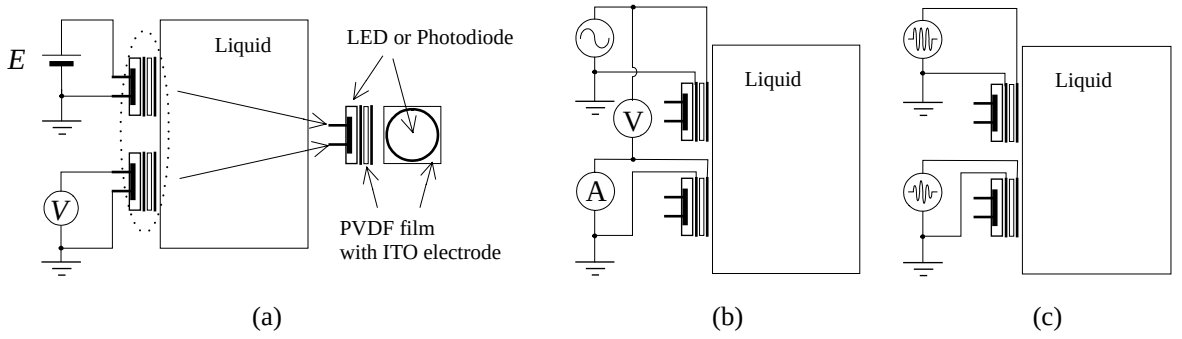

Fig. 1. Schematic diagram of proposed plane type sensor. Measurement of (a) optical property; (b) ultrasound property; (c) electrical property.

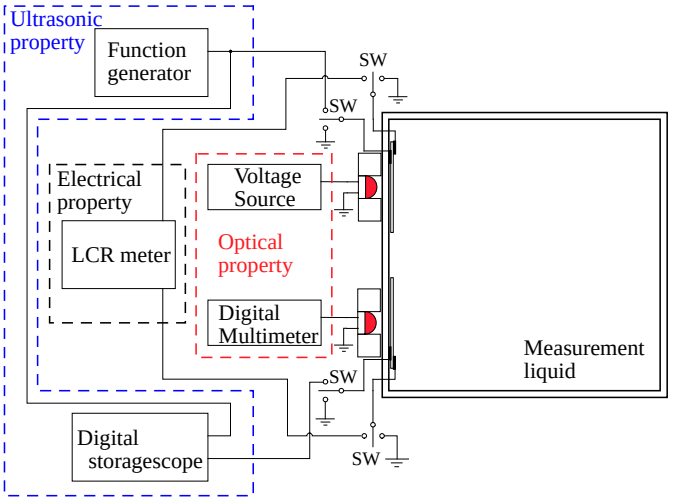

Fig. 2. Schematic diagram of measurement system

3. Experiment

Fig. 2 shows a schematic diagram of the measurement system. Measurement equipment, which is structured from polyvinyl chloride plate with black color to cut off light from the out side, (65 mm×65 mm×45 mm) is prepared. A pair of PVDF films with ITO electrodes (40 mm×30 mm×40 μm) are fixed to inside a plate of the equipment. In addition, a LED with 600 nm peak wavelength and a wavelength range from 450 to 800 nm and a photodiode with 960 nm maximum sensitive wavelength and a wavelength range from 320 to 1100 nm, with diameters of 5 mm, were respectively arranged to the backside of each PVDF film. The sample liquid was inserted in the equipment, and voltage as the optical property, conductance as the electrical property and propagation time as the ultrasonic property were respectively measured. In terms of the optical property, the LED emits light at 3.0 V and the reflected light induced at the photodiode was measured by a digital multimeter. In terms of the ultrasonic property, each PVDF film with ITO electrodes is used as the transducer and receiver. The burst wave of three sinusoidal waves with the amplitude of 10 V and the frequency of 100 kHz was given to one of the PVDF film by the function generator and the reflected wave was measured by the other. Each wave was stored to the digital storagescope and

time of flight was obtained from time interval between the transmitted and reflected waves. Conductance as the electrical property is measured by the LCR meter (Agilent, 4284A) at 1 V with a frequency of 100 kHz. The values were automatically measured by a general purpose interface bus (GPIB) and stored in a PC. They were also measured in a dark room and a 25 °C temperature-controlled box. In the experiment, the sample liquids consisted of distilled water with five amaranth powder concentrations as red color (0.1, 0.3, 0.5, 0.75 and 1.0 ppm), three glycerol concentrations (10, 30 and 50 %) and three sodium chloride (NaCl) concentrations (0.1, 0.5 and 1.0 %). Accordingly, forty-five samples of liquid were prepared.

4. Results

Fig. 3(a) shows the relationship between the detected voltage and sample liquid. From the result, the detected voltage became smaller as the amaranth powder increased because the reflected light decreased. The detected voltage was not almost changed by NaCl and glycerol concentrations. Fig. 3(b) shows the result of conductance as the electrical property. Conductance was changed by NaCl and glycerol concentrations because of the conductivity of NaCl and non-conductivity of glycerol. Fig. 3(c) shows the time of flight in the liquid as the ultrasonic property. Time of flight became smaller as glycerol and NaCl concentrations increased because the sound speed became fast. It was found that time of flight and conductance were almost constant versus the concentration of amaranth powder. These measurement results show that changes of detected voltage, conductance and time of flight versus each ingredient concentration are different. This confirms the possibility of estimating three parameters, such as amaranth

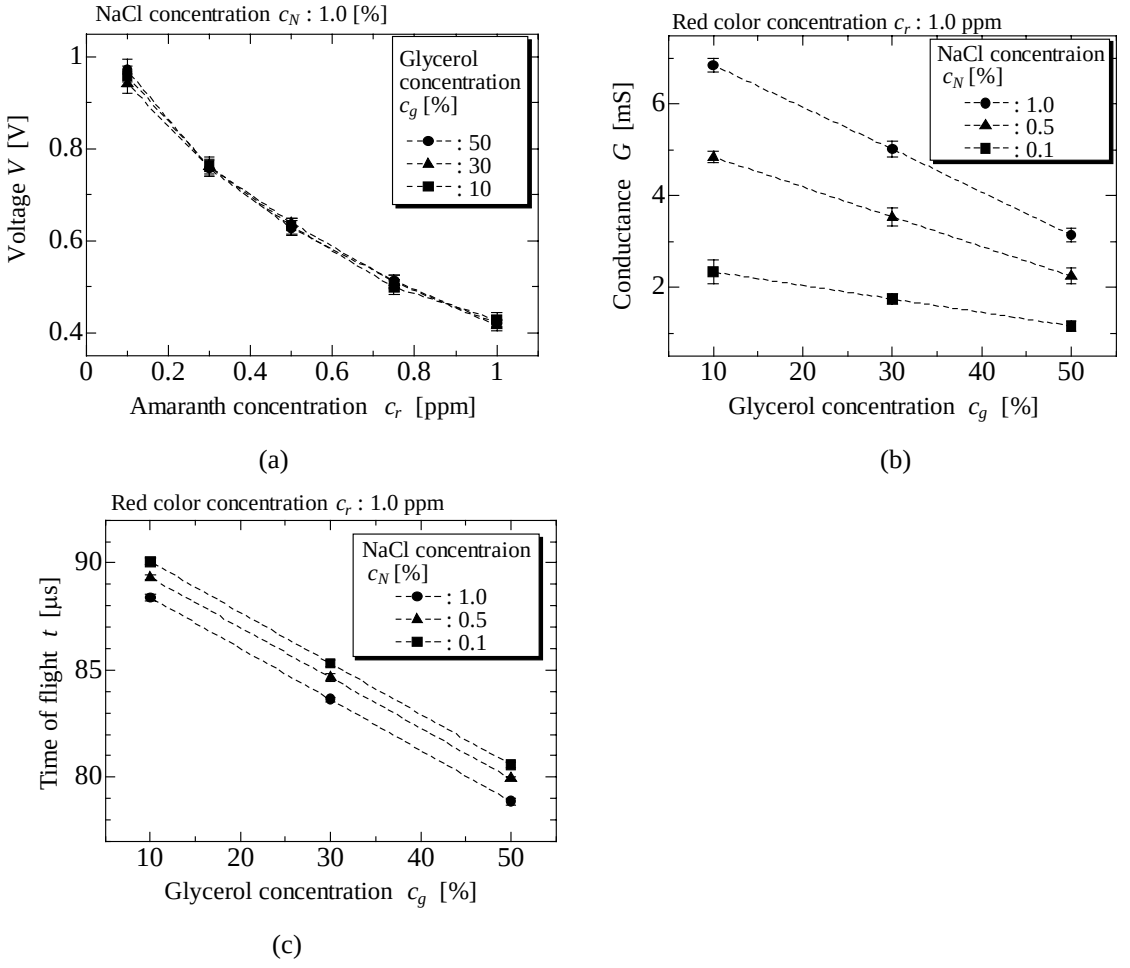

Fig. 3. Measurement results. (a) Detected voltage; (b) Conductance; (c) Time of flight.

powder, ethanol and NaCl concentrations, from detected voltage, conductance and propagation time measured by the proposed sensor.

As the estimation method, the concentration of amaranth powder is decided by the measured voltage because the voltage only depend on the concentration. The glycerol and NaCl concentrations are obtained from the measured time of flight and conductance because time of flight and conductance depend on two concentrations. Fig. 4 shows the estimated results. Each of the estimated values was calculated by using the averaged value and standard deviation at each of forty-five points shown in Fig. 3. Fig. 4 shows the estimated results. In Fig. 4, $c_{r(\mathrm{real})}$, $c_{N(\mathrm{real})}$, and $c_{g(\mathrm{real})}$ show the real concentrations of amaranth powder, NaCl and glycerol, respectively. In addition, $c_{r(\mathrm{est})}$, $c_{N(\mathrm{est})}$, $c_{g(\mathrm{est})}$, are respectively the estimated concentrations of amaranth powder, NaCl and glycerol. It was found that the estimated accuracy of amaranth powder concentration between 0.1 ppm and 1 ppm was less than ±0.07 ppm. In addition, the estimated accuracies of NaCl concentration between 0.1 % and 1 % and glycerol concentration between 10 % and 50 % were less than ±0.15 % and ±2 %.

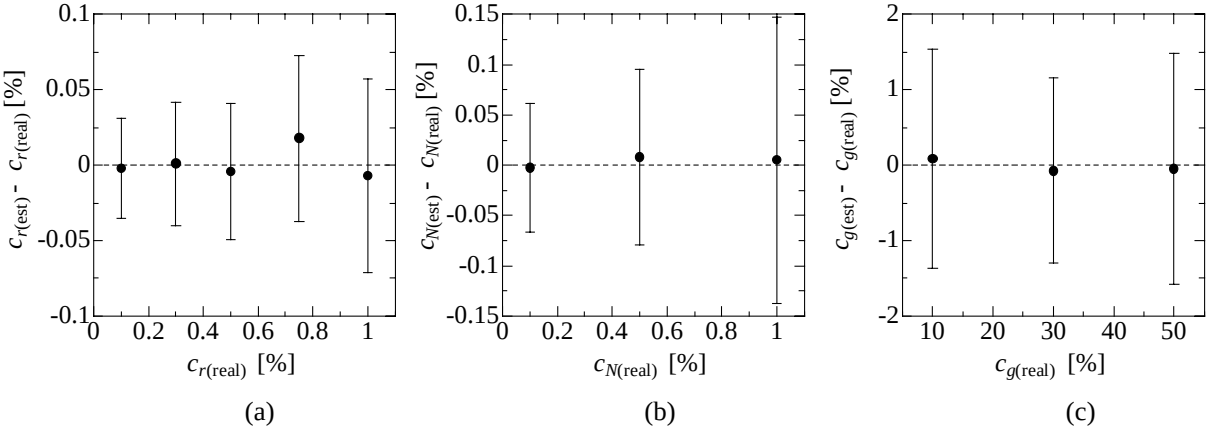

Fig. 4. Estimated results. (a) Amaranth powder; (b) NaCl concentration; (c) glycerol concentraion.

5. Conclusion

In this paper, a new plane type sensor was proposed for optical, electrical and ultrasonic measurements in a liquid. For the experiment, the liquid samples with various amaranth powder (red color), NaCl and glycerol concentrations were prepared, and detected voltage, conductance and propagation time were measured for each sample liquid. From their measured values, amaranth power, NaCl and glycerol concentrations were estimated. As resuls, estimated accuracies of amaranth powder, NaCl and glycerol concentrations were respectively within ±0.07 ppm, ±0.15 % and ±2 %. Therefore, it was suggested that estimation of three concentrations in the liquid was possible from measurements of optical, ultrasonic and electrical properties using the proposed single sensor, although there were some problems that should be improved.

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